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The efficacy of an air-cooling vest to reduce thermal strain for Light Armour Vehicle personnel

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Sponsored by Directorate of Land Requirements and Directorate of Omnibus Mounted Soldier Survivability Project

Abstract

Light armour vehicle (LAV) personnel are being subjected to high ambient temperatures and radiant heat loads for hours during recent deployments to Afghanistan. One option to reduce the heat strain of crew members is to use the existing air-conditioning discharge outlets as a source of cool air to provide microclimate cooling through an individual air-vest. In this study, seven males were exposed to either hot, dry (HD, 49ºC, 10% relative humidity) or warm, humid (WH, 35ºC, 70% relative humidity) conditions while either receiving (C) or not receiving (NC) cooling through an air-vest. Inlet temperatures during C were 20ºC and 12ºC for the HD and WH conditions, respectively, based on findings reported by Hanna (1). The air-vest was worn over a T-shirt and underneath the armour crew coveralls. Subjects also wore a fragmentation vest, helmet and gloves and sat for 3 hours during the heat-stress exposures. All subjects completed the 3 hours of heat-stress exposure during all conditions but the rise in rectal temperature approached 2ºC during HD with NC. When C was provided the rise in rectal temperature was minimal throughout the heat stress. It was concluded that micro-climate conditioning was an effective way to reduce the thermal strain of LAV crew.

Résumé

Le personnel des véhicules blindés légers (VLB) est soumis à des températures ambiantes élevées et à des charges thermiques radiantes pendant des heures au cours de déploiements actuels en Afghanistan. Parmi les options pour la réduction de la charge thermique chez les membres d'équipage, on trouve l'utilisation de sorties d'air soufflé de la climatisation existantes comme source d'air frais en vue d'assurer la micro-climatisation au moyen d'une veste à air individuelle. Dans la présente étude, sept hommes ont été exposés à des conditions de chaleur sèche (49 ºC, humidité relative 10 %) ou de chaleur humide (35 ºC, humidité relative 70 %) avec ou sans refroidissement par une veste à air. Selon les constatations de Hanna (1), les températures d'entrée avec refroidissement étaient de 20 ºC et de 12 ºC respectivement pour les conditions de chaleur sèche et de chaleur humide. La veste à air était portée par-dessus le tee-shirt et sous les combinaisons de l'équipage des blindés. Le personnel portait également une veste pare-éclats, un casque et des gants, et est resté assis pendant 3 heures durant les essais d'expositions au stress thermique. Tout le personnel contrôlé a subi les 3 heures d'exposition au stress thermique sous toutes les conditions, mais la hausse de la température rectale a approché 2 ºC pendant les essais à la chaleur sèche sans refroidissement. Avec refroidissement, la hausse de la température rectale était minimale pendant tout le stress thermique. On a conclut que le conditionnement au micro-climat était une façon efficace de réduire le stress thermique d'un équipage de VLB.

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Executive summary

The efficacy of an air-cooling vest to reduce thermal strain for Light Armour Vehicle personnel

T.M. McLellan; DRDC Toronto TR 2007-002; Defence R&D Canada – Toronto.

Introduction: Light armour vehicle (LAV) crew are being subjected to prolonged exposure to high ambient temperatures during current deployments to Afghanistan. Increases in body temperature can impact negatively on physical and cognitive function. As a result, the Directorate of Land Requirements and the Directorate of the Omnibus Mounted Soldier Survivability Project (DOMSSP) contacted DRDC Toronto through our Business Line 2 office to examine whether a micro-climate cooling system could be used to lower the thermal strain being experienced by LAV crew. The project was conducted in 2 phases with the first phase (see Hanna (1)) documenting the discharge air outlet temperatures in various regions of the LAV when the vehicle was exposed to a hot, dry desert (49ºC) and warm, humid tropical (35ºC) condition with the air-conditioning unit fully engaged. Subsequent work at DRDC Toronto then examined whether the use of an air-cooling vest worn over the T-shirt and underneath the armour vehicle coveralls could provide sufficient cooling to control the rise in body temperature during 3 hours of exposure to the hot, dry (49ºC, 10% relative humidity) or warm, humid (35ºC, 70% relative humidity) condition.

Results: During the 3 hours of heat-stress exposure to the hot, dry condition, the rise in body temperature was almost 2ºC which would be associated with errors in judgement and decision making. During exposure to the more tropical warm, humid condition the rise in body temperature was approximately 1ºC. With the use of the air-cooling vest body temperatures were controlled at close to resting levels for the duration of the heat-stress exposures.

Significance: Maintaining physical and cognitive performance at levels close to baseline amidst all of the stressors of the battlefield is an enormous task. However, if the burden imposed by exposure to the climatic extremes of the environment can be controlled with the use of a micro-climate cooling system then this allows the soldier to remain focused on other critical tasks. Certainly the use of an air-cooling or liquid-cooling system should be the aim of the DOMSSP for future light armour vehicles to ensure that the mounted soldier's ability to maintain a safe body temperature is not compromised.

Future plans: The recommendation from DRDC Toronto is for DOMSSP to proceed with either an air-cooling or liquid-cooling system for implementation into all future light armour vehicles.

Sommaire

L’efficacité d’une veste de refroidissement par air dans la réduction du stress thermique chez le personnel des véhicules blindés légers

T.M. McLellan; RDDC Toronto TR 2007-002; R et D pour la défense Canada – Toronto.

Introduction : Des équipages de véhicules blindés légers (VLB) sont soumis à des expositions prolongées à des températures ambiantes élevées au cours des déploiements actuels en Afghanistan. Les augmentations de températures corporelles peuvent avoir un effet négatif sur les fonctions physiques et cognitives. Pour cette raison, la Direction - Besoins en ressources terrestres et la Direction du Projet général d’initiative de surviabilité des soldats embarqués (PGISSE) ont communiqué avec RDDC Toronto par le biais de notre bureau de ligne d’affaires 2 afin de déterminer si un système de refroidissement à micro-climat pouvait être utilisé pour abaisser le stress thermique auquel sont soumis les équipages de VLB. Le projet a été mené en deux phases, la première phase (voir Hanna (1)) servait à documenter les températures de sorties d’air soufflé dans diverses parties du VLB lorsque le véhicule était exposé à des conditions de chaleur désertique sèche (49 ºC) et à des conditions de chaleur tropicale humide (35 ºC) pendant que la climatisation fonctionnait à fond. Au cours de travaux ultérieurs à RDDC Toronto, on a étudié l’utilisation d’une veste de refroidissement par air portée par-dessus le tee-shirt et sous les combinaisons de l’équipage des blindés pour savoir si elle pouvait refroidir suffisamment pour permettre de limiter la hausse de température corporelle pendant 3 heures d’exposition à des conditions de chaleur sèche (49 ºC, humidité relative 10 %) ou à des conditions de chaleur humide (35 ºC, humidité relative 70 %).

Résultats : Pendant les 3 heures d’exposition au stress thermique à des conditions de chaleur sèche, la hausse de température corporelle était de près de 2 ºC, ce qui peut donner lieu à des erreurs de jugement et de prise de décision. Pendant l’exposition aux conditions de chaleur tropicale humide, la hausse de température corporelle était d’environ 1 ºC. Grâce à l’utilisation des vestes de refroidissement par air, les températures corporelles ont été maintenues à tout près des niveaux de repos pendant la durée des expositions au stress thermique.

Portée : Le maintien des rendements physiques et cognitifs à des niveaux près de la ligne de base au sein même de tous les agents stressants du champ de bataille constitue une tâche énorme. Toutefois, si le fardeau imposé par l’exposition aux extrêmes climatiques de l’environnement peut être allégé par l’utilisation d’un système de refroidissement de micro-climat, alors le soldat pourrait demeurer concentré sur d’autres tâches critiques. L’utilisation d’un système de refroidissement par air ou par liquide doit certainement être l’objectif du PGISSE pour les véhicules blindés légers futurs afin d’assurer que la capacité des soldats embarqués à maintenir une température corporelle sécuritaire n’est pas compromise.

Recherches futures : La recommandation de RDDC Toronto est que le PGISSE aille de l’avant avec un système de refroidissement par air ou par liquide en vue de son intégration dans tous les véhicules blindés légers futurs.

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Acknowledgements

The author is indebted to the subjects for volunteering their time to participate in this study and for the technical support of Mr. Jan Pope who coordinated the data collection for the investigation.

1 Introduction

1.1 Background

Current deployments of CF personnel to Afghanistan have necessitated exposure to very high ambient temperatures sometimes in excess of 40ºC. Together with the need to wear fragmentation vests and other protective equipment, the body's ability to regulate its internal temperature can become compromised to the extent that cognitive and physical performance could degrade (2, 3).

Light armoured vehicle (LAV) personnel are also being subjected to high ambient temperatures and radiant heat loads for hours. One option to potentially reduce the heat stress experienced by LAV crew is to provide air-conditioning throughout the entire vehicle. A recent report revealed, however, that in both a hot, dry (49ºC, 20% relative humidity) and warm, humid (35ºC, 65% relative humidity) environment with simulated solar loads approaching 1100 W/m^2, internal LAV temperatures at the head-level of the driver approached 40ºC and 35ºC, respectively with the air-conditioning unit fully activated (1). The driver's space in the LAV includes only one discharge outlet from the air-conditioning unit over the right shoulder while the heat from the engine radiates from the left side to the driver. The discharge outlet temperatures approximated 20ºC and 15ºC during the hot, dry and warm, humid testing, respectively (1). Without redesigning the LAV crew space with additional discharge outlets, one option is to use the existing outlet as a source to provide microclimate cooling through an individual air-vest for crew members.

There is an abundance of government reports and open-literature publications that have examined the efficacy of microclimate cooling with either liquid- or air-cooled systems during exposure to hot environments. In general, these studies have shown the benefits of both cooling systems compared with no cooling in an operational scenario (4-9), the effects of cooling provided only during rest periods to simulate operational capability (10, 11), or the combined effects of ambient and conditioned air-cooling provided during exercise and rest periods, respectively (12). The Canadian Forces were actually the first nation to incorporate the use of a microclimate liquid-cooling system during wartime operations that extended mission durations for the Sea King helicopter aircrew during Operation Friction in the first Gulf War (13).

1.2 Purpose

It was the purpose of this study to demonstrate the effectiveness of an air-cooling vest for reducing the thermal stain of LAV crew during exposure to either a hot, dry or warm, humid environment.

2 Methods

2.1 Consent

The protocol was reviewed and approved by the DRDC Human Research Ethics Committee in April 2006. Following this approval, all potential volunteers were initially informed of the potential risks and discomforts associated with the experimental protocol and then they were medically screened for their health status. Only after providing written informed consent and obtaining medical clearance to proceed did volunteers begin the study.

2.2 Fitness Testing

Peak oxygen consumption ($\dot{V}O_{2peak}$) was measured at a comfortable room temperature (22°C) using open-circuit spirometry on a motorized treadmill using an incremental protocol (14). $\dot{V}O_{2peak}$ was defined as the highest observed 30-sec value for oxygen consumption ($\dot{V}O_2$) together with a respiratory exchange ratio (RER) $\geq$ 1.15. Relative values for $\dot{V}O_{2peak}$ in $mL \cdot kg^{-1} \cdot min^{-1}$ were expressed in terms of total body mass for individual subjects. Heart rate (HR) was monitored during the treadmill protocol using a transmitter/ telemetry unit (Polar Vantage XL, Finland). The highest value recorded at the end of the exercise test was defined as peak HR (HR_{peak}).

2.3 Subjects

Seven males volunteered to participate in the study. Mean values and standard deviations in parentheses for age, height, weight, HR_{peak} and $\dot{V}O_{2peak}$ were 32 (10) y, 180.6 (8.6) cm, 81.0 (12.4) kg, 190.0 (9.8) beats per minute and 50.6 (6.9) ml/kg/min, respectively.

2.4 Experimental Design

All subjects performed a familiarisation session that involved seated exposure for 3 hours at 35ºC and 70% relative humidity and 4 experimental sessions randomly assigned to complete a 2 x 2 matrix for 2 levels of cooling (abbreviated as C or NC for cooling and no cooling, respectively) and 2 environmental conditions described as hot, dry (HD, 49ºC and 10% relative humidity) or warm, humid (WH, 35ºC and 70% relative humidity). These environmental conditions are somewhat more severe than what was measured inside the LAV during overnight soaking of the vehicle to these temperatures with a subsequent 11 hours of operation of the air-conditioning unit (1). Our findings with the no cooling condition are indicative of the extent of the thermal strain that would be experienced by LAV crew if the air conditioning unit was not functional. Clearly, exposure to a lower internal LAV temperature (40ºC inside when the air conditioning unit is functional and outside temperatures are 49ºC (1)) would be associated with a lower thermal strain without additional microclimate cooling.

A minimum of 7 days separated the familiarisation session and each of the experimental sessions.

2.5 Clothing

Subjects wore the armour crew coveralls over shorts, a T-shirt, combat shirt and pants, armour crew gloves (including a temperature resistant glove insert) and combat crew helmet minus the ear cups, and socks and combat boots. The fragmentation vest was worn over the coveralls. Subjects also wore the air-cooling vest over the T-shirt and beneath the combat shirt for the cooling trials.

2.6 Dressing and Weighing Procedures

To control for the effects of circadian rhythm on rectal temperature (T_{re}), all trials began at 7:30 am (15). Upon arrival, subjects inserted a rectal probe and were weighed nude on an electronic scale, sensitive to the nearest 0.05 kg (Serta Systems Inc., SuperCount, Acton, MA). Skin thermistors and HR monitor were applied, and then subjects were dressed in the ensemble described above at which point a final dressed weight was obtained prior to entry into the climatic chamber. Inside the chamber, skin and rectal thermistor monitoring cables were connected to a computerized data acquisition system (Hewlett-Packard 3497A control unit, 236-9000 computer, and 2934A printer, Pittsburgh, PA). Upon completion of the 3 hours of exposure a final dressed weight was obtained after exit from the climatic chamber. The subject's nude weight was recorded within 5 min after being undressed and towelled dry.

2.7 Fluid Replacement

Subjects were provided with 5 ml/kg of cool tap water to drink prior to commencing the heat stress exposure and at 30-min intervals throughout the heat stress exposure. The last bolus of fluid was provided after 150 minutes of heat stress exposure.

2.8 Air-Cooling Vest

The air cooling garment was a vest made of two layers of air-impermeable urethane-coated nylon separated by a mesh spacer fabric. The inner layer of fabric is perforated with a grid of 0.125 inch diameter holes to create an air distribution manifold. A second layer of mesh spacer fabric over the perforated layer ensures an unobstructed low resistance air flow path even under the weight of heavy overgarments. Cool air for the vest was supplied by blowing air through a heat exchanger immersed in a cool water reservoir. Flow rate was 420-460 L/min and vest inlet temperature was controlled at 20.3 (0.4)°C and 12.1 (0.7)ºC to be consistent with the discharge temperatures of the air-conditioning unit measured in the driver's space of the LAV during exposure to 49ºC and 35ºC, respectively (1). Outlet temperature could not be measured because the air vest is an open system, and because of this, cooling power of the vest could not be determined.

2.9 Physiologic Measurements

2.9.1 Temperature Measurements

Mean values over 1-min periods for T_{re}, and a 7-point weighted mean skin temperature ($\overline{T}_{sk}$) (16) were calculated, recorded, and printed by the computerized data-acquisition system. T_{re} was measured using a flexible vinyl-covered rectal thermistor (YSI Precisions 4400 Series, Yellow Springs Instrument Co. Inc. Yellow Springs, OH) inserted approximately 15 cm beyond the anal sphincter. $\overline{T}_{sk}$ was obtained from 7 temperature thermistors (Mallinckrodt, Medical Inc, St. Louis, MO) taped on the forehead, abdomen, deltoid, hand, upper anterior thigh, shin and foot.

2.9.2 Heart Rate Measurements

Heart rate was monitored using a transmitter (Polar Vantage XL), attached with an elasticized belt fitted around the chest and taped in place. The receiver was taped to the outside of the clothing, allowing for a continuous HR display. HR was recorded manually every 10 min during the heat-stress exposure.

2.9.3 Gas Exchange Measurements

Details of the open-circuit spirometry used to determine $\dot{V}O_2$ have been presented previously (14). Measurements were made during the last 3 minutes of each 30-minute interval. Values were averaged from a 2-min sampling period for each subject following a 1-min washout period.

2.9.4 Thermal Comfort Measurements

Subjects were asked to provide a subjective rating of their level of thermal comfort on a 13-point scale that progressed from a rating of 1 to indicate that the individual is “so cold that I am helpless” to a rating of 13 to indicate “that I am so hot I am sick and nauseated”.

2.9.5 Sweat Measurements

During the trials, all nude and dressed masses were corrected for respiratory (17) and metabolic mass losses (18), as well as for fluid intake.

2.10 Statistical Analyses

An Analysis of Variance (ANOVA) with 2 repeated factors (cooling and environmental temperature) was performed on dependant measures that involved only one calculation such as sweat rate. For those measures sampled repeatedly over time, an ANOVA with 3 repeated factors (cooling, environmental temperature and time) was performed. To correct for violations in the assumption of sphericity with the repeated factors, the Huynh-Feldt correction was applied to the F-ratio. When a significant F-ratio was obtained, post-hoc analyses utilized a Newman-Keuls procedure to isolate differences among the treatment means. For all statistical analyses, the $p < 0.05$ level of significance was used.

3 Results

All subjects completed the 3 hours of heat stress exposure during each of the 4 experimental sessions. Nude weights at the beginning of the heat-stress exposures were similar indicating that hydration status also was unchanged among the sessions.

3.1 Oxygen Consumption

$\dot{V}O_2$ averaged 0.4 L/min or approximately 4.5 ml/kg/min throughout the heat-stress exposures reflecting a very low level of metabolism due to the resting condition. There was a small but significant elevation in $\dot{V}O_2$ during the hot, dry exposure most likely reflecting the Q_{10} effect of the higher body temperatures (see below) recorded during these sessions.

3.2 Thermal Comfort

Ratings of thermal comfort were elevated throughout the NC compared with the C heat-stress exposures. Values for the NC sessions over the 3 hours averaged 9.7 (1.1) and 9.0 (1.0) for the HD and WH conditions, respectively. Comparative respective values during the C sessions were 7.6 (0.9) and 5.7 (0.9). There was a significant condition and cooling interaction indicating that the difference between scores during the NC trials was less than during the C sessions.

3.3 Delta Rectal Temperature

Figure 1 presents the change from baseline (or delta) in T_{re} over time for the 4 experimental sessions. Clearly, the air-cooling vest was effective in lowering the rise in thermal strain over time with a significant reduction becoming evident in both the HD and WH conditions after 70 minutes. It should also be evident that exposure to the HD environment, regardless of whether cooling was present, was associated with greater thermal strain indicating the greater heat stress associated with exposure to this environment.

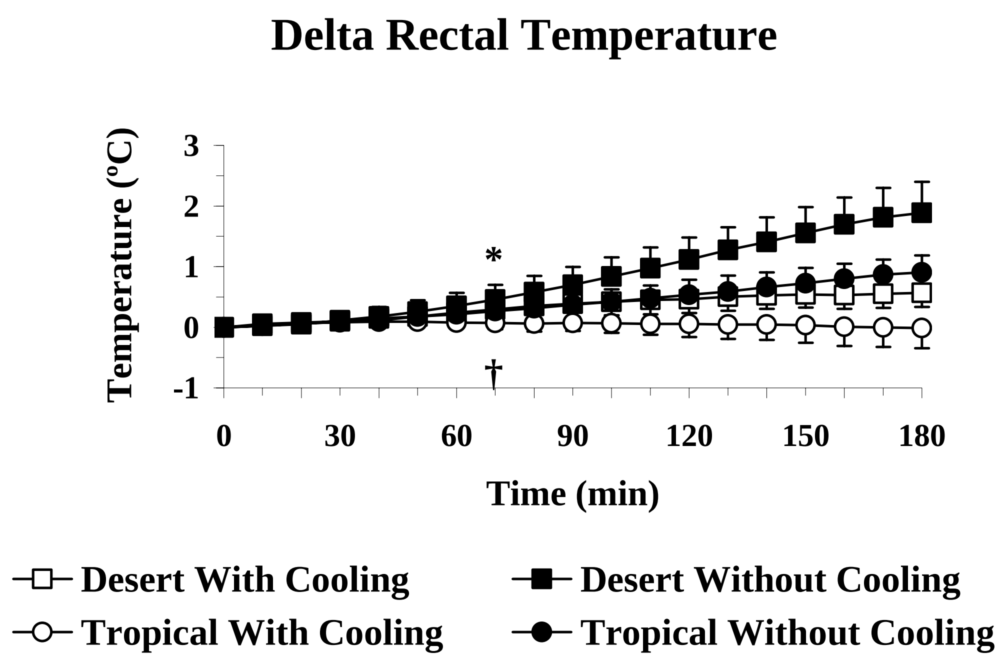

Figure 1: The change from baseline (or delta) rectal temperature over 3 hours of heat-stress exposure to either a hot, dry desert (49ºC and 10% relative humidity) or warm, humid tropical (35ºC and 70% relative humidity) condition with or without cooling provided through an air-cooling vest worn under the armour crew coveralls. The asterisk and cross indicate a significant difference between the cooling and no-cooling conditions after 70-min of exposure for the desert and tropical environments, respectively.

3.4 Mean Skin Temperature

Figure 2 presents the change in $\overline{T}_{sk}$ throughout the 4 heat-stress exposures. Since the cooling vest was turned on during the C conditions just before the exposure commenced $\overline{T}_{sk}$ was reduced at the beginning of the sessions for both of the C compared with the NC sessions. $\overline{T}_{sk}$ was significantly reduced throughout the 3 hours of heat-stress exposure when the air-cooling vest was worn regardless of the environmental heat-stress that was imposed. The response over time was similar between the HD and WH conditions when either C or NC was received.

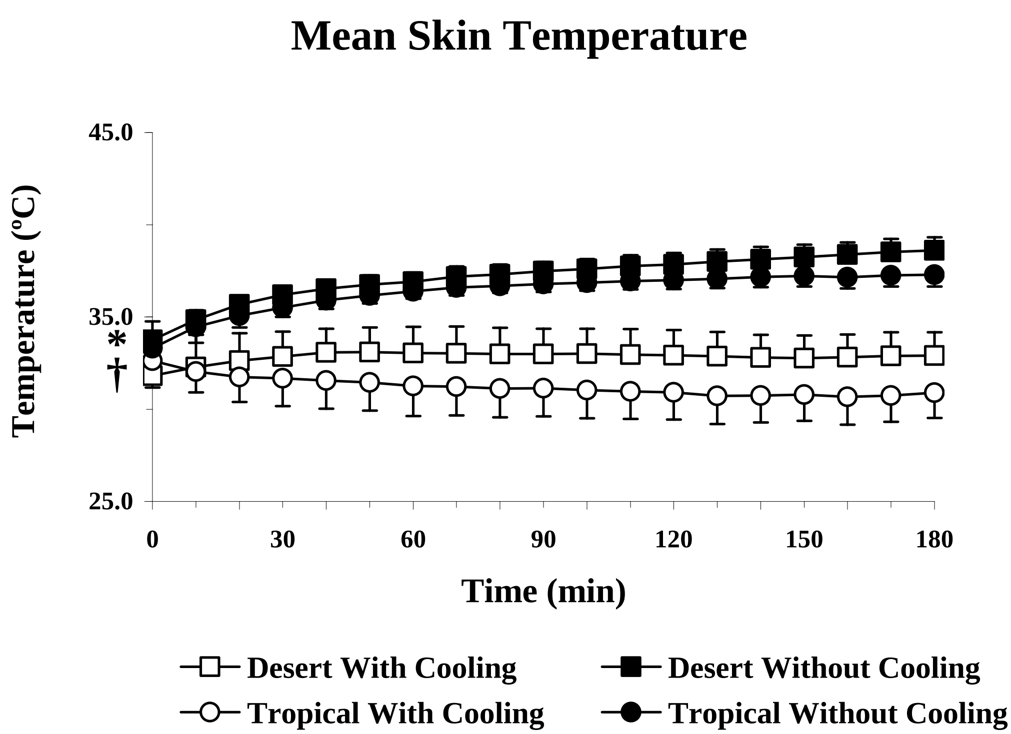

Figure 2: Mean skin temperature over 3 hours of heat-stress exposure to either a hot, dry desert (49ºC and 10% relative humidity) or warm, humid tropical (35ºC and 70% relative humidity) condition with or without cooling provided through an air-cooling vest worn under the armour crew coveralls. The asterisk and cross indicate a significant difference between the cooling and no-cooling conditions throughout the heat-stress exposure for the desert and tropical environments, respectively.

3.5 Heart Rate

Figure 3 presents the heart rate response throughout the 4 heat-stress exposures. Cooling significantly reduced the cardiovascular strain, as indicated by heart rate, during both the HD and WH conditions with the beneficial effect of cooling being evident sooner in the latter condition. The HR response was also higher during the HD condition especially when NC was received.

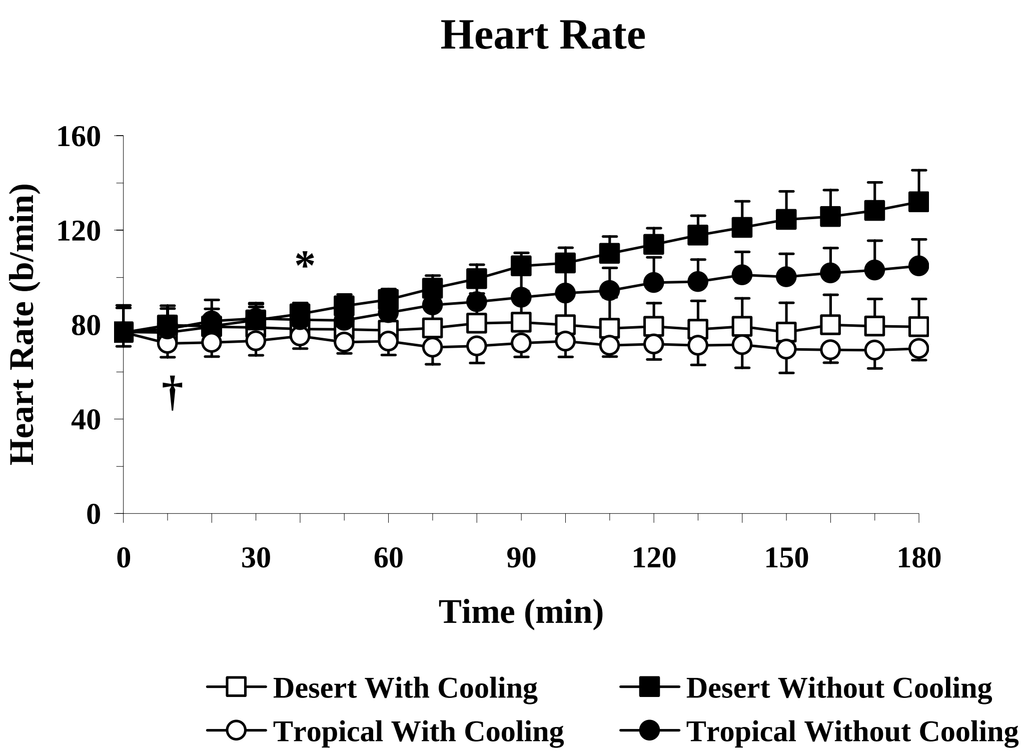

Figure 3: Heart rate over 3 hours of heat-stress exposure to either a hot, dry desert (49ºC and 10% relative humidity) or warm, humid tropical (35ºC and 70% relative humidity) condition with or without cooling provided through an air-cooling vest worn under the armour crew coveralls. The asterisk and cross indicate a significant difference between the cooling and no-cooling conditions after the indicated time of the heat-stress exposure for the desert and tropical environments, respectively.

3.6 Sweat Rate

Sweat rates were higher during the HD (0.40 (0.26) L/h) compared with the WH (0.27 (0.19) L/h) trials and lower when C (0.17 (0.12) L/h) was received compared with the NC (0.50 (0.20) L/h) sessions.

4 Discussion

The data clearly show the advantage of providing microclimate cooling to lower the thermal strain of LAV crew. If air-conditioning were not available or not functioning, internal temperatures in the LAV during the summer months in Afghanistan could be similar or greater than those that represented the HD condition in the present study. The almost 2ºC increase in T_{re} during the HD condition with NC would be associated with potential errors in decision making and judgement (2). The necessity for cooling under these environmental conditions would be further magnified by an elevation in metabolic rate, compared with a level indicative of rest, that would be associated with driving the LAV.

The final cooling power delivered by the air-vest is a function of the air flow and inlet temperature. Inlet temperatures were controlled at values representing discharge temperatures of the air-conditioning outlets in the LAV (1) when the vehicle was exposed to the ambient temperatures defined as HD or WH. However, it was difficult to measure flow rates in the present study and quite clearly it is uncertain exactly what flow rates would be manageable in the LAV if individual cooling vests were connected to the discharge outlets. If airflow was insufficient to deliver sufficient cooling to the individual then LAV crew could still experience a significant increase in thermal strain during the conduct of operations.

Other options exist to provide a source of microclimate cooling such as a liquid-cooling garment that was used successfully for our Sea King helicopter aircrew during the first Gulf War (13). This system does require a refrigeration unit to maintain blocks of ice and thus space on-board the LAV would need to be designated for this purpose. Direct comparisons between the air-cooling and liquid-cooling garments has shown little, if any, difference when worn under biological and chemical defence clothing (9). It is most likely, therefore, that a liquid-cooling undergarment would provide sufficient cooling to reduce the level of thermal strain as was evident for the air-cooling vest used in the present study.

It should be noted that the level of thermal strain during the WH condition without C would not be associated with physical and cognitive impairments. Although subjects felt uncomfortable (because of a wet skin) they were able to dissipate sufficient amounts of heat through the evaporation of sweat to minimise the increase in body temperature after 3 hours of heat-stress exposure. However, as mentioned above, if the rate of heat production or activity level were increased and/or the duration of heat-stress exposure were increased then the level of thermal strain could easily approach the values noted during the HD exposure without cooling. It is also interesting to note that when C was applied during the WH condition T_{re} actually decreased towards the end of the heat-stress exposure (see Figure 1). In other words, the amount of cooling provided was greater than that required to maintain thermal equilibrium and a marginal heat debt was incurred. One option that could be considered for the instrumentation of the micro-climate cooling system is to allow the soldier to self-regulate the cooling power based on their own subjective symptoms of thermal comfort. Not all of the environmental conditions would necessitate the use of full cooling power to reduce thermal strain and, as such, a self-regulating system would seem desirable.

One issue that would need to be considered with the use of a cooling-vest is the added thermal resistance of the vest worn under conditions where cooling was not applied. If the crew members

were required to exit the LAV without sufficient time to remove the vest then their rate of increase in thermal strain would be greater in their role as a dismounted soldier because the vest would act as an additional layer of clothing to impede heat transfer. However, if the fragmentation vest was always worn this additional thermal resistance could be inconsequential because of the impermeable nature of the body armour.

5 Summary and Recommendations

The results of this study have clearly identified the benefits of a micro-climate air-cooling vest to lower the thermal strain for the mounted soldier in the LAV. Rectal temperature, as an index of thermal strain, and heart rate, as an index of cardiovascular strain, were significantly reduced when cooling was provided during exposure to both the hot, dry desert and warm, humid tropical conditions.

Although an air-cooling vest was used in the present study to demonstrate the efficacy of directing the discharge from the air outlets close to the skin surface of the soldier, a liquid-cooling system could be equally as effective if air-conditioning was not to be included in the design of future light armoured vehicles.

Whichever micro-climate cooling system is selected, the system should allow the soldier to self-regulate the extent of the cooling received. This self-regulation could be as simple as an easy on/off switch or a quick and easy way to connect and disconnect the tether of the cooling vest to the source of the cooling power.

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List of symbols/abbreviations/acronyms/initialisms

ANOVA	Analysis of Variance
C	Cooling
CF	Canadian Forces
DRDC	Defence Research and Development Canada
HD	Hot, Dry
HR	Heart Rate
HR_{peak}	Peak Heart Rate
LAV	Light Armour Vehicle
NC	No Cooling
Q_{10}	The proportional change in metabolism for a given 10ºC increase in body temperature.
R&D	Research & Development
RER	Respiratory Exchange Ratio
$\overline{T}_{sk}$	Mean Skin Temperature
T_{re}	Rectal Temperature
$\dot{V}O_2$	Oxygen Consumption
$\dot{V}O_{2peak}$	Peak Oxygen Consumption
WH	Warm, Humid

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Light armour vehicle (LAV) personnel are being subjected to high ambient temperatures and radiant heat loads for hours during recent deployments to Afghanistan. One option to reduce the heat strain of crew members is to use the existing air-conditioning discharge outlets as a source of cool air to provide microclimate cooling through an individual air-vest. In this study, seven males were exposed to either hot, dry (HD, 49ºC, 10% relative humidity) or warm, humid (WH, 35ºC, 70% relative humidity) conditions while either receiving (C) or not receiving (NC) cooling through an air-vest. Inlet temperatures during C were 20ºC and 12ºC for the HD and WH conditions, respectively, based on findings reported by Hanna (1). The air-vest was worn over a T-shirt and underneath the armour crew coveralls. Subjects also wore a fragmentation vest, helmet and gloves and sat for 3 hours during the heat-stress exposures. All subjects completed the 3 hours of heat-stress exposure during all conditions but the rise in rectal temperature approached 2ºC during HD with NC. When C was provided the rise in rectal temperature was minimal throughout the heat stress. It was concluded that micro-climate conditioning was an effective way to reduce the thermal strain of LAV crew.

Le personnel des véhicules blindés légers (VLB) est soumis à des températures ambiantes élevées et à des charges thermiques radiantes pendant des heures au cours de déploiements actuels en Afghanistan. Parmi les options pour la réduction de la charge thermique chez les membres d’équipage, on trouve l’utilisation de sorties d’air soufflé de la climatisation existantes comme source d’air frais en vue d’assurer la micro-climatisation au moyen d’une veste à air individuelle. Dans la présente étude, sept hommes ont été exposés à des conditions de chaleur sèche (49 ºC, humidité relative 10 %) ou de chaleur humide (35 ºC, humidité relative 70 %) avec ou sans refroidissement par une veste à air. Selon les constatations de Hanna (1), les températures d’entrée avec refroidissement étaient de 20 ºC et de 12 ºC respectivement pour les conditions de chaleur sèche et de chaleur humide. La veste à air était portée par-dessus le tee-shirt et sous les combinaisons de l’équipage des blindés. Le personnel portait également une veste pare-éclats, un casque et des gants, et est resté assis pendant 3 heures durant les essais d’expositions au stress thermique. Tout le personnel contrôlé a subi les 3 heures d’exposition au stress thermique sous toutes les conditions, mais la hausse de la température rectale a approché 2 ºC pendant les essais à la chaleur sèche sans refroidissement. Avec refroidissement, la hausse de la température rectale était minimale pendant tout le stress thermique. On a conclut que le conditionnement au micro-climat était une façon efficace de réduire le stress thermique d’un équipage de VLB.

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Air-Cooling Vest, Thermal Strain, Mounted Soldiers